State-of-the-Art: Land Use in LCA

Expert Workshop on Land Use Impacts in Life Cycle Assessment (LCA)

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Abstract

Goal, Scope and Background. On June 12–13 June 2006 in Guildford (UK) an international workshop was held to address indicators to incorporate land use impacts in LCA. It provided an interdisciplinary forum where soil scientists and biologists met with LCA experts and users to discuss the challenges of including land use impacts in LCA and potential approaches to addressing these challenges. The discussion used as starting point the definitions framed in the past work on land use impacts within the UNEP/SETAC Life Cycle Initiative (Milà i Canals et al. 2006). However, the presence of soil quality and biodiversity experts allowed for a more in-depth consideration of the nature of land use impacts.

Main Features. The discussions were focused on three main themes: general methodological issues to be addressed in including land use impacts in LCA; recommendations for soil quality indicators; and recommendations for biodiversity indicators.

Results and Discussion. There is a conflict between the levels of detail at which LCA should assess land use impacts: a coarse assessment may allow the detection of hotspots from a life cycle perspective, whereas a more detailed assessment might allow the distinction between land management modes (e.g. organic vs. conventional agriculture). Different land use processes need to be modelled in consequential and attributional LCA. Land use effects on biodiversity and soil quality are non-linear and also depend on the scale of land use, which is difficult to address in LCA. Soil is multi-functional and many threats affect its quality, which results in a case-specific selection of the most adequate indicator. In the case of biodiversity, two main options for defining indicators were identified at species and ecosystem levels. The main advantage of the former is data availability, but the election of a particular taxon may be arbitrary. Ecosystem level indicators include a higher degree of subjectivity but may be more relevant than species level ones.

Conclusions. Land use impacts need to be considered in LCA for all life cycle stages in all types of products. An urgent need for LCA is to incorporate land use impacts particularly in comparisons of systems which differ substantially in terms of land use impacts. The main differences between consequential and attributional LCA are the need for the consideration of off-site effects and marginal vs. average land uses in consequential LCA. In order to define the marginal effects of land use a similar approach to the description of the electricity grid and its marginal technology may be followed. 'Dose-response' functions need to be defined for land use interventions and their effects. The main soil degradation processes (considering soil's vulnerability to different threats) should be captured in a spatial-dependent way in LCA. Criteria and examples to select biodiversity indicators at species and ecosystem levels were proposed in the workshop.

Recommendations and Perspectives. The conduction of LCA case studies for relevant systems (especially fossil energy compared to bio-energy systems involving different eco-regions to account for potential international trade) may provide a good platform to further develop the workshop suggestions.

Keywords: Biodiversity; impact assessment; land use; land use impacts; LCA; soil quality; workshop

Introduction

Accounting for land use in LCA is inherently problematic. Land represents a scarce resource, yet it is not simply consumed like mineral or fossil energy reserves, in the sense that it is not extracted and dissipated. However, its functioning, both economic and non-economic, depends on how it is managed. Concern for the importance of land in preserving biodiversity means that the instrumental approach to resource use which is the normal LCA perspective is not sufficient in this context: humans are not the sole users of land and therefore the effects of human land use on other species should be included in any assessment. Biodiversity and soil quality are two measures, amongst others, which may enable land use to be treated systematically in LCA.

The two-day expert workshop on Definition of Best Indicators for Biodiversity and Soil Quality for Life Cycle Assessment (LCA), organised by the Centre for Environmental Strategy (University of Surrey, UK) on 12 and 13 June 2006, brought together LCA practitioners with biodiversity and soil scientists. The main goal of the workshop was to identify any relevant impact pathways that are not represented by biodiversity and soil quality (which is interpreted to in-

clude both biotic production potential and ecological soil quality), and to investigate operational ways to implement indicators for these impact pathways. The general framework for land use impact assessment that served as a starting point for the workshop discussions is published in Milà i Canals et al. (2006). On the first day, plenary presentations were given to provide a basis for discussion on the main topics of the workshop; on the second day the participants were divided into sub-groups for focussed discussions on specific topics. The presentations and the minutes of the discussions held at the workshop can be found on the workshop website (http://www.soc.surrey.ac.uk/ias/workshops/DEFNBEST/report.php); these presentations are referred to in the present paper with the surname of the author only, and do not appear in the reference list. This paper summarises the main discussion points and conclusions from the workshop, divided into the following main themes:

1. General methodological issues to be addressed in including land use impacts in LCA
2. Recommendations for soil quality indicators
3. Recommendations for biodiversity indicators

Section 4 provides conclusions and some suggestions of research needs.

1 General Methodological Issues to be Addressed in Including Land Use Impacts in LCA

It was stressed that all relevant environmental effects caused by a product system need to be included in a LCA, and therefore one should always include land use effects such as impacts on biodiversity and soil quality. However, there is still no consensus on the most appropriate methodologies for doing this. Some specific methodological concerns discussed during the workshop are as follows.

1.1 Appropriateness of using LCA to consider the impacts of land use

In general, different communities of LCA practitioners expect different things from the consideration of land use impacts, which demands clarification of the type of decisions that require information on the impacts of land use and the identification of those that need to be supported by LCA. In general, LCA seems appropriate to bring a life cycle perspective to support complex decisions where the scope of other tools (e.g. Environmental Impact Assessment, Environmental Risk Assessment) is too limited or inappropriate. However, LCA may not be adequate to aid in concrete land management decisions where other tools may be more appropriate. Two different perspectives on this issue were identified in the workshop:

– First, one can treat land use impacts as additional figures in the current list of categories used in the LCIA profiles; this is the perspective of most LCA practitioners, who focus on *products* and their assessment and need to know how to relate the impacts on land quality *to the functional unit* of the system under consideration, e.g. impacts per m^2 of wooden floor, or per kg of bread.
– Alternatively, one can try to use LCA to help in land management decisions in sectors which make extensive use of land; this is the perspective of some LCA practitioners and many scientists outside the LCA community who are developing land quality indicators, and need to focus on the effects of *land use and management* practices on land quality.

In the first case, one needs to derive impact scores on soil quality and biodiversity for processes using land in any part of the life cycle of a product. Land use processes should be defined as basic inventory elementary flows in terms of land transformation (m^2) and land occupation (m^{2}year), including the type of land used and the intensity of use along with the relevant bio-geographical information. The impact assessment stage should define characterisation factors linking the elementary flows to the relevant impact indicators. In the second perspective, one needs to address all the elementary flows and impact categories for a full LCIA profile of the land use activity. It is not clear whether LCA is a good tool for land management considering the existing set of tailored tools and methodologies (such as Environmental Impact Assessment), and the participants could not reach agreement on the level of analysis that LCA should focus on.

Some participants felt that the level of detail at which LCA can provide meaningful results is the comparison of systems which differ quite substantially e.g. crop/forest systems, or bio-based/fossil-based products. This is a burning issue because no other tools will compare these systems from a life cycle perspective, whereas the comparison may be crucial e.g. in the field of bio-energy. It was suggested that other tools are probably more appropriate for higher levels of detail such as crop vs. crop, or comparison of land management systems such as organic vs. conventional farming. One of the reasons adduced for this is that comparing land management systems requires a level of detail that could only be obtained in the foreground system (e.g. agricultural stage), but would not be applicable for the hundreds of additional processes to be modelled in the background system. However, some other participants expressed concern that LCA would be much less useful if it could not address the distinction between management modes (e.g. organic vs. conventional crops). The situation is further complicated by the observation that the same land use type (e.g. agricultural land) can generate differences of orders of magnitude on land quality measures, and LCA should be able to capture at least these big changes (see e.g. Cederberg).

1.2 Reference land use

The direction taken within the LCA community for the definition of a reference situation against which one can measure land use impacts ('dynamic reference situation' as defined by Milà i Canals et al. 2006) goes very much in line with what is being suggested by the Impact Assessment (IA) community: using a historic (or climax) baseline is meaningless, and a more meaningful approach is to use 'what will actually happen in the absence of the proposed activi-

ties'. Another possibility currently being discussed is using a value-based perspective as a baseline. i.e.: trying to find the land quality desired by people.

1.3 Temporal system boundaries for the assessment of land use impacts

Two main issues related to the setting of the temporal system boundaries were discussed during the workshop:

- Allocation of the initial transformation impacts
- Assumption of natural relaxation (spontaneous and gradual rebound of land quality due to the forces of nature once land is abandoned; Milà i Canals et al. 2006)

First, the framework does not clarify how to allocate the impacts from a land transformation when this is followed by many successive land uses benefiting from the initial transformation (e.g. an originally forested area cleared 400 years ago and then cropped for 400 years; see Fig. 1 in Milà i Canals et al. 2006). In general, if the initial transformation was intended specifically for the current land use, part of the initial impacts should be allocated to the current land use. However, if the current land use has continued for a long time (e.g. 400 years of cropping), the amount of initial impact allocated to a unit of functional output will be minimal and could be neglected. In each case, thus, the practitioner should provide evidence on whether initial transformation can be neglected compared to the impacts derived from land occupation. It is important to note that the problem of allocating the impacts of 'preparative' processes to the subsequent 'productive' processes is not a specific problem of land use impacts. In fact, most processes to produce functional units are based on buildings, machinery and other infrastructural elements that have been prepared before the beginning of the 'useful life' of these investments. These impacts from 'capital goods' are often excluded from LCA studies because they are negligible when allocated over a certain amount of functional output. However, they often need to be included because of their relevance (e.g. water dam for electricity production; agricultural machinery; etc.); this is likely to be the case in initial land transformations.

The perspective on past transformations is different for consequential LCA, though. As discussed by Kløverpris, if the LCA is used to describe the consequences of a change (or continuation) in land use (consequential LCA), then the initial transformation 200 years ago is of no consequence. What really matters are the potential transformations occurring elsewhere in the world due to the studied system, i.e. in a world with increasing population and increasing pressure on land, a change in land use in one area (e.g. from food crop to bio-energy crop in Europe) will lead to an increased pressure and possibly transformation of currently ‘natural’ areas into new human land uses in other areas (e.g. in the developing world) due to the need to continue to produce the products of the initial land use (i.e. food crops). In this case, identifying the location and affected land types is a key part of the LCA. If pressure on land was declining, then any new marginal increase in land use would simply postpone the re-naturalisation of currently used land: in this case, only occupation impacts are relevant. An important point is that the identification of the affected areas is actually an issue for the inventory (LCI) stage, but has a crucial effect on the LCIA.

It was also suggested that it would be difficult to obtain data on natural relaxation for many of the processes involved in a LCA. The assumption on natural relaxation is central in the framework for land use impact assessment (Milà i Canals et al. 2006), and it was suggested to derive relaxation times for known regions (e.g. Europe) and then discuss whether these will change widely in other regions of the globe as a possible way forward (Müller-Wenk).

Additional to this point, it is sometimes clear that, following a particular land use, human-induced restoration activities will take place (e.g. in mining sector). In these situations the environmental costs of these activities need to be included in the overall environmental profile, as well as the (positive) effects of human-induced restoration on land quality (i.e. reduced relaxation time and therefore reduced land use impacts).

1.4 Nature of land quality indicators and suitability for LCA

Category indicators need to be defined for the impact categories related to land use, namely 'biodiversity' (already existing as an endpoint), 'biotic production potential' and 'ecological soil quality', and equivalency factors for land use elementary flows need to be developed for these impact categories.

LCA methods for impact assessment have traditionally assumed that there is a linear relationship between intervention and impact. However, effects on biodiversity and soil quality are generally non-linear, and also the scale of impact is important. One approach to this problem is to disregard this issue and use a (simplified) linear characterisation factor relating the m^2 or m^2year used to the impacts on biodiversity and soil quality. Alternatively, efforts should be put into defining 'dose-response' functions for land use interventions, in a similar way to other impact categories (e.g. acidification).

As for the characteristics of these indicators, they need first of all to have a *predictive* capacity. Additionally, it needs to be clarified which types of indicators (e.g. pressure or state) work better in LCA, and be aware that different scientific communities (e.g. biodiversity scientists and soil scientists) currently work towards indicators which are different in nature: while soil indicators seem to be essentially measures of the resource *state*, biodiversity indicators look at the *pressure* on the resource, and anticipate the probability of discontinuous change rather than measuring incremental change. This should be an issue of concern for the interpretation stage of the LCA. Relative values, rather than absolute, are required as LCA indicators (e.g. 'loss of 5% of species', not 'loss of 15 species').

In general, indicators should be selected because they express the endpoint that we want to protect (soil quality,

biodiversity) AND because they are sensitive only to the management practices we want to assess. Some changes occur naturally e.g. occurrence of some species changes seasonally or due to other factors independent of the studied management system; nutrient status of soil changes swiftly due to many factors apart from management; hence indicators need to have a slow natural rate of change in order to highlight the effects from management systems.

1.5 Considerations for consequential vs. attributional LCA methodology

In contrast with attributional LCA, where only those sites/situations/impacts that are part of the product life cycle should be assessed, consequential LCA should also study the land use changes in other sites caused by the studied system (see e.g. Kløverpris; Lesage). It was felt that 'marginal land uses' rather than 'average land use' should probably be the focus of attention in consequential LCA. The methodological difference to incorporate these effects is in system modelling, and therefore this distinction affects the inventory stage more than the impact assessment stage. It was suggested that LCIA indicators should ideally be the same in both approaches.

1.6 Need for spatial differentiation in land use impact assessment

Traditional LCA with spatial-generic impact assessment is not satisfactory for biodiversity and soil quality impact assessment: regional-dependency is a necessity if the LCA results are to be meaningful from a land use impacts perspective. Eco-regions[1] are certainly an improved level of spatial differentiation (rather than political boundaries) particularly for biodiversity, but even at this level there is a lack of background data. In the case of soil quality, variations within the same eco-region are probably still too wide. However, the approach and indicators should be the same in all regions and sectors, as the results will have to be aggregated over the life cycle. This was identified as being quite problematic because the drivers for biodiversity loss and soil degradation vary between different sectors and eco-regions.

2 Recommendations for Soil Quality Indicators

Many specific indicators for soil quality were mentioned and discussed during the workshop. These were mostly derived for agricultural land management, and so are focused on the resource value of land for biomass production. An addition to the soil quality indicators commonly discussed in LCA literature was the use of mycorrhizal communities, which play a crucial role particularly in forest soils, and can also be used as indicators of system recovery. The main point of agreement was that it is unlikely that a universally acceptable indicator for soil quality can be derived that will be meaningful for all land uses and soil types, and therefore a set of indicators is likely to be required.

The main limitation with such sets of indicators, as often recognised in the literature, is that aggregation to a single index for soil quality is not obvious. One potential way forward identified in the group discussions is the inclusion of the concept of *vulnerability to degradation* (related to soil resilience, see Romanyà), defined as the distance to a degradation threshold. This is a general idea that might also be extended to other effects with critical thresholds. Degradation thresholds need to be defined for each degradation threat, and are dependent on the eco-region and management system (e.g. irrigated/non-irrigated agriculture). The final indicator chosen for soil quality should depend on the threat that is closest to the critical threshold, and be defined according to threat-specific 'dose-response' curves, on a relative scale. The steps to select the soil quality indicator and assess the effect of the studied system on soil quality can thus be described as:

1. Identify relevant threats to soil quality: compaction, chemical contamination, soil loss, salinisation, etc.
2. Define indicators and the 'dose-response' functions for each threat
3. Determine the distance to each threat threshold (system quality *state*)
4. How does the system affect the distance to the threshold? (*pressure* from studied system)

Wienhold et al. (2004) distinguish three main types of 'dose-response' curves according to indicator behaviour:

- 'More is better' indicators: soil depth, SOC, Cation Exchange Capacity (CEC)…
- 'Less is better' indicators: bulk density, soil loss, electric conductivity?…
- 'Middle point indicators': pH…

The implementation of such a framework requires extensive collection of data at the local level, and related to soil management. It is quite unlikely that these data will be available soon on a global level through e.g. world maps. Consequently, this approach might not be suitable for the broader perspective of LCA applications, as the information required is possibly only available for specific life cycle stages such as agricultural production. Another possibility for soil quality assessment within LCA would be to work with land classes, in a similar approach to that used by many methods for biodiversity assessment in LCA, whereby competition between different uses should be assessed according to land's productive capacity (e.g. do not build on Class I soil, and preserve this for food production or for biodiversity).

3 Recommendations for Biodiversity Indicators

In general, it is difficult to identify biodiversity indicators that are cross-regional (how does biodiversity in a tropical rainforest compare to biodiversity in a semi-arid zone?) or cross-sectoral (e.g. it is easy to find indicators for tilled agriculture: earthworms? But how are these to be compared to an indicator for the effects of mining?). On the other hand it would probably be more straightforward to compare management practices in agricultural systems within the same eco-region and it may be more realistic and practical to limit attention to indicators for this kind of purpose (e.g. Rydgren).

A common assumption to be questioned is that 'more biodiversity is better', as more invasive species are not desired, whereas ecosystems naturally low in species numbers need to be protected. It was also stressed that no attention is be-

[1] As defined by WWF: http://www.worldwildlife.org/wildfinder

ing paid to marine environments, even though on a global scale and from a life cycle perspective they may be crucial.

The main discussion point on biodiversity indicators revolved around how to better indicate the values of biodiversity that need protection. The current trend in IA points towards assessing what we want to achieve rather than effects on a particular species (value driven indicators rather than purely science based). It was stressed that the technocratic perspective where Nature conservation is seen as separate from human life needs to be avoided to get the buy-in of the rest of the world: we need to include what has value for people.

The discussion on value-driven vs. purely science-based indicators is closely related to the level at which the indicators to measure biodiversity are defined. Two broad options seem to be available:

- Use specific taxonomic groups or even single species (e.g. vascular plants; key taxa involved in ecosystem services such as pollinators, decomposers, etc.), recognising that the chosen taxonomic groups may not be comparable across different regions or sectors. There is a trade-off between completeness (ideally all taxa should be assessed) and practicality (data availability)
- Measure effects on ecosystems. The comparison of ecosystems only seems to make sense within the same eco-region, and they need to be rated. This is inherently a normative assessment, depending on stakeholder values and priorities, so that it must be addressed as a public engagement problem with no pretence of expert 'scientific objectivity'

The discussion in the workshop did not reach a consensus on whether one option is better than the other; however, useful suggestions on criteria to select taxonomic groups as biodiversity indicators and of indicators at ecosystem level were made. These are discussed in turn below.

3.1 Criteria to select taxonomic groups as biodiversity indicators

The first criterion should be that data are available, in order to start incorporating biodiversity in LCA soon (e.g. vascular plants). Other useful criteria are:

- Ease of measurement, taxonomy known ('the bigger the better')
- Species which can serve as measurable proxies (e.g. arthropod populations frequently correlate strongly with populations of birds and other predators)
- Keystone species (crucial for environmental services: pollinators, decomposers, nutrient cycling, etc.)
- Charismatic species (especially significant for local communities)
- Invasive, weed, alien and feral species (look at 'undesirable' species as indicators of degradation)
- Taxa sensitive to disturbance or land use (e.g. sensitive to soil tillage, epiphytic orchids, etc.)
- Threatened taxa
- Succession indicators

It was also pointed out that belowground biodiversity is not generally included in the current indicators, and it needs to be brought forward as it may be even higher than aboveground biodiversity. However, an important issue with soil biodiversity is lack of data.

3.2 Examples of biodiversity indicators at ecosystem level

Some potentially useful indicators were identified that work at ecosystem level. They were discussed in terms of LCA data requirements (**Table 1**).

4 Conclusions, Perspectives and Research Needs

The main conclusions from the workshop are:

- Land use impacts need to be considered in LCA, not only of activities which make extensive use of land but for all life cycle stages in all types of products.
- The traditional site-generic LCA methodology is not satisfactory for land use impacts, as has been previously discussed for other impact categories (e.g. acidification, eutrophication, etc.).
- LCA is considered a suitable tool to incorporate land use impacts particularly in comparisons of systems which differ substantially in terms of land use impacts (e.g. en-

Table 1: Examples of ecosystem-level indicators for biodiversity

Indicator	Land management information	Environmental mechanism	Eco-region information	Relevant bio-geographical parameters
Intactness (Scholes and Biggs 2005): proportion of the original groups of species present in different land use types	Background/dynamic reference situation	Indirect effects on 'neighbouring' areas, driving change elsewhere ('neighbouring' is used in the LCA sense: land affected by the studied land use, even if it occurs elsewhere in the world)	Knowledge on species response to land use	Species distribution lists and land use maps
Integrity (Scholes and Biggs 2005): fully functioning vs. non-functioning ecosystems	The supporting environment (and key environmental functions) 'allowing' biodiversity to exist, e.g. pollinators	What are the key functions guaranteeing ecosystem viability/integrity e.g. maintenance of water flow to a wetland	Key functions and processes	n.t.
Fragmentation (Schenck 2006)	Remote sensing info, spectral signatures identified	Occupation driving reduced connectivity	Footprint of activity and remote sensing data	n.t.
Endemism (Treweek and Bubb 2006): high proportions of endemic species indicate high biodiversity value	n.t.	Bird endemisms are a good proxy, as birds move and therefore show a quick response to pressure	n.t.	n.t.
Scarcity (Michelsen 2006)	n.t.	n.t.	n.t.	n.t.

n.t.: there was no time to discuss this aspect

ergy production from energy sources obtained from forests vs. agriculture vs. mining).

- It is important to strive towards more detailed assessments to illustrate, in a life cycle perspective, the effects of different management practices for similar types of land and uses (e.g. organic vs. conventional crops).
- System modelling differences for attributional and consequential LCA studies have been identified and described – key to this is the consideration of off-site effects and marginal vs. average land uses in consequential LCA.
- The effects of marginally increasing/reducing demand for land could be defined in a similar way as was done for energy systems some years ago (definition of an agricultural 'electricity-grid').
- Many degradation processes affect soil, and LCA should be able to capture the most relevant in a spatially-dependent way. An approach was suggested considering the resilience and vulnerability of soil to the different threats according to the distance to thresholds beyond which the soil quality becomes much more sensitive to stress. A similar but more extreme approach is to consider the distance from 'tipping points' at which the system switches to another state; this involves considering the possibility of discontinuous (and, in the short term, irreversible) change rather than continuous response curves.
- In the case of biodiversity indicators, there is no clear consensus on the preference for species vs. ecosystem level indicators. The potential ease-of-use of the first contrasts with the importance to incorporate the more qualitative information (e.g. ecosystem scarcity, degree of fragmentation, etc.) captured by ecosystem level indicators. The decision on the type of indicators is left for the practitioner, and some criteria and examples to select indicators were proposed in the workshop discussions.

The conduction of LCA case studies of systems in which consideration of land use impacts is essential (e.g. activities which make an extensive use of land, land-based vs. abiotic-based products, etc.) could provide a good platform to address the research needs that follow from the above conclusions. A specially relevant case study requiring the incorporation of land use impacts in LCA, which is of the utmost importance in the current energy policy context, is the comparison of energy sources (e.g. bio-energy A vs. bio-energy B vs. fossil energy). It would be important to include different eco-regions to account for the potential international trade in energy crops. It is recommended that these studies be used to further develop the suggestions made here with regard to biodiversity and soil quality indicators for LCA.

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References

Milà i Canals L, Bauer C, Depestele J, Dubreuil A, Freiermuth Knuchel R, Gaillard G, Michelsen O, Müller-Wenk R, Rydgren B (2006): Key elements in a framework for land use impact assessment in LCA. Int J LCA, OnlineFirst <DOI: http://dx.doi.org/10.1065/lca2006.05.250>

Scholes RJ, Biggs R (2005): A biodiversity intactness index. Nature 434 (3 March 2005) 45–49

Wienhold BJ, Andrews SS, Karlen DL (2004): Soil quality: A review of the science and experiences in the USA. Environmental Geochemistry and Health 26, 89–95

Key Elements in a Framework for Land Use Impact Assessment Within LCA

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Abstract

Background, Aims and Scope. Land use by agriculture, forestry, mining, house-building or industry leads to substantial impacts, particularly on biodiversity and on soil quality as a supplier of life support functions. Unfortunately there is no widely accepted assessment method so far for land use impacts. This paper presents an attempt, within the UNEP-SETAC Life Cycle Initiative, to provide a framework for the Life Cycle Impact Assessment (LCIA) of land use.

Main Features. This framework builds from previous documents, particularly the SETAC book on LCIA (Lindeijer et al. 2002), developing essential issues such as the reference for occupation impacts; the impact pathways to be included in the analysis; the units of measure in the impact mechanism (land use interventions to impacts); the ways to deal with impacts in the future; and bio-geographical differentiation.

Results. The paper describes the selected impact pathways, linking the land use elementary flows (occupation; transformation) and parameters (intensity) registered in the inventory (LCI) to the midpoint impact indicators and to the relevant damage categories (natural environment and natural resources). An impact occurs when the land properties are modified (transformation) and also when the current man-made properties are maintained (occupation).

Conclusion. Guidance is provided on the definition of the dynamic reference situation and on methods and time frame to assess the impacts occurring after the actual land use. Including the occupation impacts acknowledges that humans are not the sole users of land.

Recommendations and Perspectives. The main damages affected by land use that should be considered by any method to assess land use impacts in LCIA are: biodiversity (existence value); biotic production potential (including soil fertility and use value of biodiversity); ecological soil quality (including life support functions of soil other than biotic production potential). Bio-geographical differentiation is required for land use impacts, because the same intervention may have different consequences depending on the sensitivity and inherent land quality of the environment where it occurs. For the moment, an indication of how such task could be done and likely bio-geographical parameters to be considered are suggested. The recommendation of indicators for the suggested impact categories is a matter of future research.

Keywords: Biodiversity; bio-geographical differentiation; dynamic reference situation; land quality; land use; land use impacts; LCA; LCIA; natural environment; natural resources; site-dependency; soil quality